Automating the Reclaimed Construction Material Supply Chain: A Western Ontario Case Study

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Abstract:
Sustainability is currently one of the most researched topics in the construction industry, yet there is still much to learn about how resources journey back through the reclaim process. Using a case study from the Western Ontario region, this paper examines the Reverse Logistics (RL) process for Reclaimed Construction Materials (RCM) and the potential for improving existing process through automation. An assessment of informal interviews of managers and stock taking (e.g. reclaimed doors, windows, flooring, wood, masonry) at RCM distribution centers across Ontario inform the formalization of the RL supply chain and reveals the challenges faced in the supply chain process. The data collected during the field study enables the identification of potential ways to implement cloud-based inventory systems and automation technologies like 3D scanning, IoT devices, and robotics. Thus, through the utilization of the PESTEL framework and Nvivo, a strategic management and textual analysis tool, distribution center processes can be effectively examined to develop appropriate strategies to tackle existing challenges. The study provides valuable insights into the materials returning to the RCM distribution centers and their management for post-use. It also sheds light on management challenges at these centers and suggests potential outcomes by digitizing the RL process. Finally, the study highlights the necessity of automating RCM supply chains and the need to enhance existing infrastructure models to enable the flow of resources back into buildings.
Keywords: Reverse logistics, Cloud-based inventory, Reclaimed building materials, Western Ontario field study, Digital resource management tools.

1. Introduction

Reverse Logistics (RL) is recognized as a strategic approach to tackle waste management across various sectors, including the construction industry. It encompasses the processes and operations associated with returning post-consumption goods to the productive cycle, effectively reversing the distribution channel [1]. As discussed in [2], RL is deemed as a supply chain (SC) that has been restructured to facilitate the movement of products for remanufacturing, recycling, or disposal, thereby enhancing resource utilization. Therefore, in the construction industry, the practice of RL differs from the conventional take-make-waste model of the traditional supply chain, which linearly consumes resources and disposes of them at the end of their lifecycle, significantly affecting the environment [1]. To mitigate resource wastage, the concept of a circular value chain is promoted for strategies to close, narrow, or slow the loop. Closing the loop ensures that resources exiting one lifecycle can seamlessly transition into a second lifecycle, as often as necessary [3].
Although, there are several approaches to minimizing waste production in the construction industry, significant gaps exist in understanding the processes that ensure material wastage is limited. Currently, the construction industry contributes about 40% of the total waste materials that end up in landfills [4], and of the materials diverted from landfills, majority face a lengthy journey back from the extraction process [4]. Many resources remain unused on lots or in warehouse storage for years before they can be repurposed or purchased for reuse. The RL supply chain in the construction industry is currently unstructured, which negatively affects the efficiency of reintegrating resources back into the resource cycle [5]. As resources remain unused, they often degrade in quality and subsequently require more effort and resources to refurbish or reintegrate. Therefore, the quicker resources re-enter the RL supply chain, the more efficient the process becomes. Consequently, maximizing the benefits derived from these resources. Several studies, including [1,4,6–8], have highlighted the barriers in construction reverse logistics, a topic that has gained prominence in the construction industry in recent years. The discussion mainly focuses on the barriers to using or extracting reclaimed construction materials. There is a significant lack of understanding about the state of materials at intermediate points, leaving the question what happens to materials when they are diverted from the landfills? How are the materials found and used? The gap represents a developing area of study within construction RL. Materials undergo several steps and stages before potentially being reused, with their workflow heavily influenced by location, variability, and available opportunities. Currently, there is no standardized method for assessing the reusability of materials, with such decisions being made independently and often without clear guidance.

Stakeholder assessments of the RL landscape has been addressed using various methods [7, 8]. One approach involved using multi-criteria decision models

to examine and extract viewpoints related to companies, customers, and government in relation to the RL supply chain. Through the applied methodology, the barriers identified include logistical and governmental barriers, particularly in terms of legislation and agencies, along with customer and client preferences. Other notable issues were the lack of technical skills among personnel, insufficient IT standards for assistance, and inadequate implementation of technologies for product recovery. Additionally, technology and research development challenges were highlighted, as well as difficulties with supply chain members, indicating a coordination shortfall [7]. Furthermore, the literature review in [8] identified organizational issues as significant challenges within the RL supply chain. Among other issue, the notable issues are the impact of labor-intensive processes on the end value of building materials, and the process of sourcing materials which is typically manual, making decisions about salvageable materials subjective. An aspect which is predominantly managed by intermediary players.

Another study, [9] used a textual analysis software known as Nvivo, to facilitates both qualitative and quantitative assessments to explore and analyze the perceptions of South Australian construction practitioners regarding reverse logistics. The study examined transcripts from eight practitioners within the supply chain. These included roles such as the CEO of a demolition company, an executive manager, a managing director, a marketing manager, a senior Environment Protection officer, and an architect. The findings from this study highlighted the significance of various drivers in the adoption of reverse logistics.
However, surveys assessing the RL process for reusing building components often gather information from notable figures in the field, such as architects, engineers, and end-users [7-9]. Therefore, a significant gap exists in understanding the perspective of intermediaries, specifically those who collect and source materials from demolition sites. These middlemen, who often operate through reclaim distribution centers play a crucial role in redirecting resources back into new structures. Despite their importance, the insights of these intermediaries have not been extensively explored. Gaining an understanding of how these individuals select, source, and price salvaged items is crucial for promoting effective salvage practice within the reclaimed construction material supply chain.

Thus, the current study aims to bridge the gap by examining the experiences of reclaim distribution centers situated in Western Ontario. It assesses the components that are collect, their collection methods, and the challenges in managing inventory using the PESTEL framework through textual analysis in Nvivo. The research reveals the complex dynamics of the RL process in the building industry, providing invaluable insights that can advance sustainable construction practices.

2. Methodology

The methodology used by Hosseini et al. (2014) to analyze transcripts with the software package Nvivo is also employed in this study for the objective analysis of transcripts from two main distribution centers in western Ontario. Unlike the approach in Hosseini et al. (2014), this study further refines the method of transcript analysis by incorporating the PESTEL framework. The framework enables the examination of issues related to political, economic, social, technical, environmental and legal factors. Additionally, the study utilizes the platform to discern the existing workflows of these particular intermediaries, investigating their knowledge of the RL process and their interactions with materials, from the demolition stage to their arrival at the distribution centers. The approach aids in understanding the flow of materials from the deconstruction stage to the distribution centers and eventually, their repurchase for use.

The study commenced with the transcription of approximately 3 hours of recorded memos using Microsoft Word. These transcripts were then imported into Nvivo. The data was systematically analyzed based on the PESTEL framework. By firstly creating six coding nodes in Nvivo to classify the statements in the transcripts according to: workflow, political statements, environmental statements, social statements, technical statements, economic statements, and legal statements. The classification aimed to capture the context and content of the interviews, facilitating the identification of major pain points for the distribution centers.

The primary data collection focused on two distribution centers, which provided the bulk of the insights. Additional information from the other distribution centers helped gauge the available resources. Following the coding of the data in Nvivo, an analysis pertaining to each PESTEL category was carried out, examining the statements and highlighting specific challenges that are encountered at the distribution centers. The study then compared these findings with existing literature to explore potential solutions addressing the identified issues at the various locations.

3. PESTEL and Workflow Analysis using Nvivo

Owners of the distribution centers often trade resources extracted from construction projects. These individuals visit construction sites to estimate the potential value that can be extracted from the buildings. They determine which materials are to be extracted and which are left for landfill. These decisions are largely based on the buyer’s perception of the quality of the material assessed in the field. After assessing these materials, the buyers may transport them to their warehouses for storage. These materials are then brought out for stock when supplies

run low, or they are kept on site at the distribution centers to be sold for use or repurposed for other products, such as furniture.

The unpredictable flow of resources significantly hinders the planning and execution of material selection and reservation. The opportunity to salvage materials often encounters barriers, such as storage or timing, which hinder the acquisition of these materials. Figure 1 illustrates the workflow from the construction stage to the delivery of materials at the distribution centers. The assessed distribution centers exhibit similar workflows, which are aggregated and detailed in Figure 1. In addition, the process of finding and selling materials at these two distribution centers are also detailed in Figure 1. Although the approach to trading used materials at these centers is similar, there are some differences. Distribution center A offers the option to source some materials online, yet this online sourcing process is not fully automated and lacks in some areas. Meanwhile, the other distribution center adheres to the traditional approach of in-store purchasing.

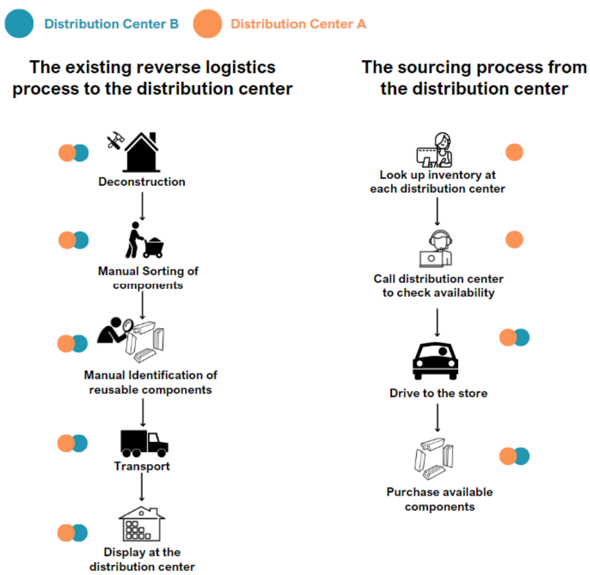

Figure 1: Reverse Logistics Workflows.

Political Factors: During the visit to the distribution centers, discussions predominantly centered on the economic, social, and technical factors. However, there was some mention of distribution center A's broader role beyond the resale of salvaged materials. Notably, it operates as a nonprofit housing developer, facilitating the creation of homes for less privileged individuals. Within this context, it was mentioned that the distribution center A benefits from partnership with government. For instance, they are sometimes given access to older, decommissioned city infrastructure, for use in their projects.

Economic Factors: Regarding the economics, it was noted that at distribution center A, the majority of the funding for building developments is derived from the sale of salvaged materials. However, economic challenges at distribution center A include tracking goods, as the current inventory system does not estimate the value of goods until they are sold. Consequently, the center relies on cashiers to accurately enter the sale amount in the books, without a possibility to audit and confirm the accurate sale price.
Distribution center A and B also experiences difficulties in setting prices. Distribution center B, states that prices are typically set based on comparable resources at similar distribution centers. The team depends on expertise and experience to price items. The usual approach involves looking up a similar establishment in the US, examining the types of items they have, and then checking online for comparable prices before setting their own prices based on these findings.

Social Factors: During the discussions with distribution center A and B, the social challenges revealed overlaps in the customer base of both centers. Both distribution centers cater to individuals and contractors seeking resources for various projects, often of a smaller scale. Contractors focusing on projects, like restaurant renovations, sheds, basement renovations etc, frequent these distribution centers. At distribution center B, however, there is significant patronage from conservationists aiming to preserve old infrastructure and maintain the older building stock.
Furthermore, Distribution Center B is perceived as not fully realizing its potential impact on the community it serves. As the manager stated, “We really feel like we are not capturing at all the entire environmental impact of what we do. It is like reclaimed wood is sort of fashionable, and it is because of its patina than its sustainability. We feel like we could really be pushing more of the environmental aspect of it.”

Technical Factors: The technical aspects of the RL process are notably complex. At distribution center A, there are hurdles such as the late issuance of permits necessary to acquire resources, which then leads to a rushed salvage operation at demolition sites. However, the challenge of physically processing and cleaning up these resources for reuse is substantial, resulting in many viable materials being sent to landfills. The distribution center coordinator also noted the logistical challenges:
“There's been 48 houses taken down recently, so we went in all those to see what was salvageable. But none of the bricks were salvageable. It was the timeframe. Where would it go? We don't have the time to leave it on their property. So, there's a whole market of bricks that are still in great shape that we just can't touch.” The statements underscore the tight timelines and logistical challenges in salvaging materials, which hinder the efficiency of resource recovery from demolition sites. Similarly, at distribution center B, managers must be present at

demolition sites to determine which resources can be salvaged, relying heavily on their expertise. The variability in resource types, due to each infrastructure's unique design and materials, further complicates the standardization of processes. The manager at distribution center B described the situation:

"Either I am on site or it arrives here, then we decide. But each demolition project is different. It's different stuff, different sizes, all kinds of stuff. It's a little bit Christmas morning every single time. We always find something cool about a particular place." The lack of a structured approach to sourcing materials limits the information available about these resources and their uniqueness.

Environmental Factors: Regarding environmental considerations, both distribution centers significantly divert resources away from landfills, using different methods. Distribution center A operates on a nonprofit model that relies on charity, handling a wide variety of resources. The center primarily accumulates materials sourced from old house scraps. It also has over 100 partners within the same network, of all the 9 partners visited for distribution center A, they had a unique set of resources available at the different locations namely; kitchenettes, vanities, windows, doors, wardrobes, furniture, skirting, lighting, floor tiles ,wiring, banisters, and wooden elements. In contrast, Distribution Center B adopts a slightly different approach by partnering with construction companies to monetize structural resources salvaged from infrastructures. Consequently, it does not gather resources of varying types but instead focuses on collecting specific structural elements. These include wooden elements from the structure, as well as steel beams, columns, staircases, banisters, and other housing components like windows and doors.

Legal Factors: Regarding the legal aspects, both Distribution Center A and B face significant barriers. A primary challenge is verifying the quality of resources sourced at these centers, resulting in stringent requirements for material use. At distribution center B, individuals purchasing materials must have an engineer certify the quality of each material before use, affecting the economic value of the materials. Similarly, at distribution center A, there is an obstacle in obtaining housing insurance when salvaged materials are utilized in the construction process.

4. Discussions

Although both distribution centers play a significant role in diverting resources away from the landfill, there is no clear metric to measure the extent of this diversion. The two distribution centers operate under different models, influencing the environmental impact of the resources in various ways. Distribution Center B adopts a direct approach, sourcing directly from partners within the industry. In contrast, distribution center A relies on being approached with opportunities to source materials.

A major challenge attributed to both distributions centers is the recertification of their material performance. In this case, there is a need to focus on opportunities to develop tools that can enable certification and also adjust building requirements and policies to allow easier integration of used resources.

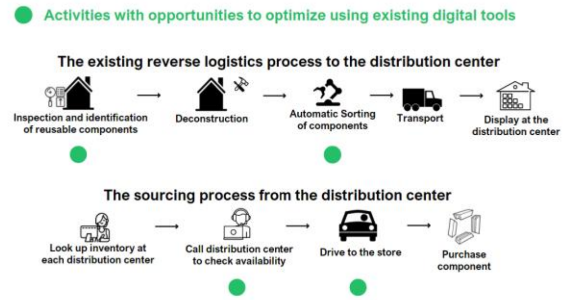

Figure 2: Oppurtunities to implement digital tools.

Furthermore, the technical setbacks are a major factor in both distribution centers. Previous research, [10–16] explored various technological tools for resource management in construction. These studies discuss the application of digital tools for virtual resource management, utilizing cloud-based inventory systems, blockchains, digital twins, optical devices, the Internet of Things, robotics, BIM, material passports, and other tools.

To effectively adopt the technologies at the intermediary stakeholder level, it is necessary to understand and facilitate their integration with existing workflows, as shown in Figure 2. For example, blockchain technology, as discussed in [13,14], can be used at the intermediate level to track resources through the collection, transportation, and usage stages. Optical devices also offer the potential to accurately capture the dimensional characteristics of resources before and after extraction, contributing to an online inventory that is accessible and responsive to users, thereby reducing the complexities of resource distribution [17]. The literature study in [18] investigated various tools and technologies for extracting information on materials for reuse. Such a model could facilitate a tailored approach to determining which tools are best suited for extracting valuable information from resources salvaged from buildings, thus supporting informed decision-making during inspection.

5. Conclusions and outlook

In conclusion, this study has outlined the workflow for the RL of reclaimed building materials at the intermediary level, focusing on the actors involved in sourcing and inventory management of these resources on a small scale. There is considerable potential for the growth and expansion of businesses dealing in reclaimed construction materials. However, the current unstructured nature of the field, hinders the expansion of this particular business model.

To support similar actors crucial to the circular economy, it is imperative to address the limitations faced by these distribution centers. Future studies should explore how the adoption and use of technologies can mitigate the challenges.

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